LWS/Space Environment Testbed End-to-end Data System Concept[1][2]

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Abstract—NASA's Living With a Star Space Environment Testbed Project includes technology validation missions on two-year centers over the next solar cycle. Budget constraints dictate that the SET Project seek partnering and other cost saving opportunities wherever possible. This includes accepting rides as secondary payloads on other, unrelated spacecraft. The SET Project has developed the concept of a standard experiment carrier that will allow experiments to be developed to a standard set of interfaces so that only the carrier modules interfacing to the host spacecraft need to be modified for a particular mission. Similarly, in the ground segment, the interface to investigators is standard, and only the interface between the SET operations control center and the host mission control center will need to be customized to meet specific host mission requirements.

This paper describes the end-to-end data system that allows investigators to access the SET control center, command their experiments, and receive data from their experiments back at their home facilities, all using the Internet. The major space and ground elements of the system are described. The paper describes data flow through the system, from invsetigator facilities connecting to the SET operations center via the Internet, communications to SET carriers and experiments via host systems, to telemetry returns to investigators from their flight experiments. It also outlines the techniques that will be used to meet mission requirements, while holding development and operational costs to a minimum.

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1 INTRODUCTION

NASA has initiated the Living With a Star (LWS) Program to develop a better scientific understanding to address the aspects of the connected Sun-Earth system that affect life and society. A principal goal of the program is to bridge the gap between science, engineering, and user application communities. The Space Environment Testbed (SET) Project is one element of LWS. The Project will enable future science, operational, and commercial objectives in space and atmospheric environments by improving engineering approaches to the accommodation and/or mitigation of the effects of solar variability on technological systems.

The SET Project is highly constrained in terms of budget and must seek partnering and other cost saving opportunities wherever possible. This includes looking for rides as secondary payloads on other, unrelated spacecraft. The SET Project has developed the concept of a standard experiment carrier that will allow experiments to be developed to a standard interface for power, data, thermal and mechanical requirements. When a particular host spacecraft is identified, only the carrier modules interfacing to the host spacecraft needs to be modified. Similarly, in the ground segment, the interface to investigators is standard, and only the interface between the SET mission operations control center and the host mission control center will need to be customized to meet the requirements of the host mission.

The SET data system is conceived to be simple to implement and operate, but at the same time to incorporate significant flexibility to take advantage of as yet undetermined partnering opportunities for access to space and in other areas. It is also designed with the objective of using as much existing NASA, other government, and commercially available capability as possible. There are no requirements for any custom ground hardware elements.

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The SET end-to-end data system includes flight and ground elements, some of which are under the control of the SET project, some of which are external to the project. Figure 1 presents a conceptual layout of the overall system.

The end-to-end data system allows Principle Investigators (PIs) to access the SET control center, command their experiments, and receive data from their experiments back at their home facilities, using the Internet. The system also interfaces with the host mission control center and spacecraft, and supports carrier interaction with SET experiments. The system supports the operational needs of SET missions, but is also available, in modified configuration during the development and checkout phases of missions.

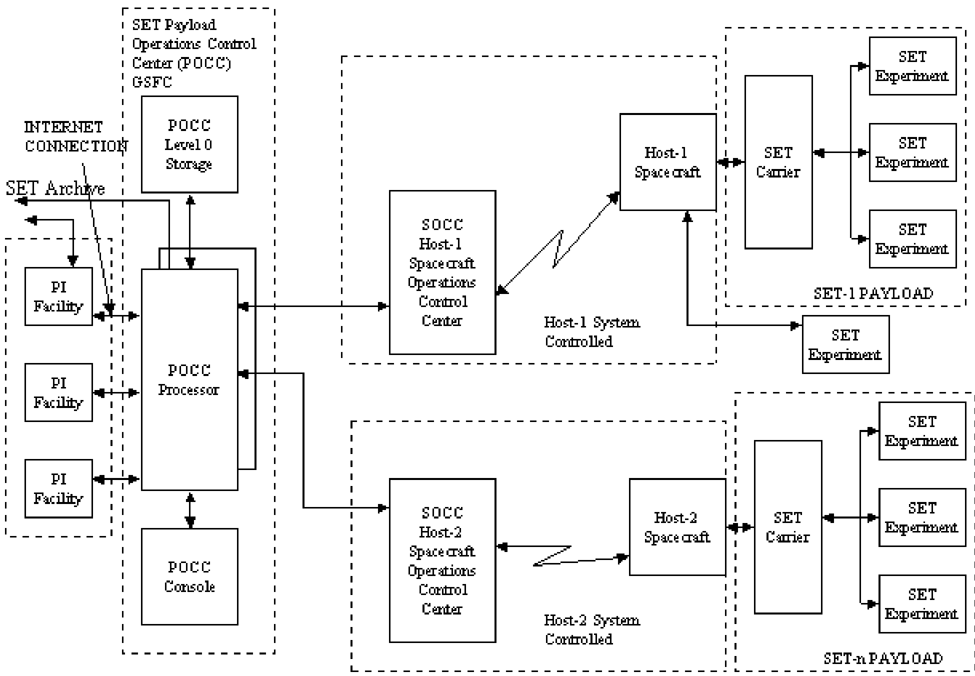

Figure 1. SET End-To-End Data System Overview

The end-to-end data system enables experiment PIs to request command initiation to control the actions of their experiments flying on SET missions, and to access experiment data and status telemetry from their experiments. The system also allows SET mission controllers to command SET payloads (carrier and suite of experiments), to receive data and telemetry from SET experiments and the SET carrier. The system must additionally deliver experiment data directly to the SET Data Archive, when allowed by SET data sharing rules and constraints. SET data will be deposited in this data archive, and SET investigators will develop data products from their data, which will also be maintained in the Archive.

Mission Phases

The end-to-end data system will be capable of supporting the following mission phases for each SET mission in the manner described:

- <u>Development:</u> during this phase (prior to Payload Flight Readiness Review (FRR)), elements of the end-to-end data system will be available for testing of performance requirements by experiments and SET carriers. Other capabilities of the system will be simulated by the SET Simulation Lab. Capabilities available are detailed in the remainder of this document.
- <u>Payload flight readiness checkout:</u> during this phase a formal test of the flight elements of the end-to-end data system will be conducted. The SET Simulation Lab will simulate host and ground system elements.

- Host spacecraft integration and checkout: during host checkout, full end-to-end data system operational capabilities will be available as needed to support integration of the SET payload with its host spacecraft.
- Launch and host spacecraft on-orbit checkout: limited support is anticipated during this phase as it is expected that the SET payload will be powered down, except during checkout of the SET payload. During that checkout, full end-to-end data system operational capabilities will be available.
- Operations: full operation of the entire SET end-to-end data system
- Post mission archiving: post mission archiving support is the responsibility of the SET Archive element of the Project and is not further considered in this paper.

The end-to-end data system will be capable of supporting multiple missions simultaneously, each at a different mission phase.

During the development and payload flight readiness checkout phases, the SET Simulation Lab will be used to simulate various elements of the end-to-end data system. The Simulation Lab will also be available during all mission phases for analysis and trouble–shooting.

2 SYSTEM OVERVIEW

The end-to-end data system enables experiment PIs to request command initiation to control the actions of their experiments flying on SET missions, and to access experiment data and status telemetry from their experiments. The system also allows SET mission controllers to command the SET carriers and experiments, to receive data and telemetry from SET experiments and the SET carriers. The system must additionally deliver experiment data directly to the SET Data Archive, when allowed by SET data sharing constraints.

While all of the capabilities described above are implemented in the end-to-end data system design, there may be operational restrictions or constraints imposed by project or mission management that prohibit use of some features. The capability to allow or disallow use of system functionality is also built into the design of the system.

The major components of the end-to-end data system are as follows:

- GSFC Payload Operations Control Center (POCC)
    - SET Payload Operations Control Center Processor
    - SET Payload Operations Control Center Console
    - SET Payload Operations Control Center Level 0 Data Storage
- SET Payload
    - SET Carrier
    - SET Experiments
- GSFC SET Simulation Lab
- SET Experiment PI Facilities
- Host System
    - Host Spacecraft Operations Control Center (SOCC)
    - Host Spacecraft
    - Ground Network Elements
- SET Data Archive

The Host Spacecraft Operations Control Center (SOCC) and the Host Spacecraft are essential links in the end-to-end data system, but are not directly under the control of the SET Project. Formal interfaces will be established between these entities and elements of the SET Project as follows:

- POCC to Host SOCC Interface Control Document (ICD
- Host Spacecraft to SET Carrier ICD
- Host Spacecraft to Box Experiment ICD (as needed)

While it is recognized that there are other components to the ground system between the SOCC and the host spacecraft (ground network, ground receiving/transmitting stations, etc.) these elements should be transparent to SET Missions. To the extent that they are not, any requirements that they levy on SET will be addressed in the POCC to Host SOCC, Host Spacecraft to SET Carrier, and Host Spacecraft to Box Experiments ICDs.

In addition to the external ICDs listed above, the end-to-end data system will require the following internal ICDs to be negotiated:

- PI Facility to POCC ICD
- SET Carrier to Experiment ICD (part of the overall carrier to experiment ICD)
- POCC to SET Archive ICD

3 SYSTEM DATA FLOW

Commanding

The SET commanding structure described here is based on a number of assumptions. Most importantly, each SET experiment will operate with a small number of command states (less than 10), including power on/off, safe mode, diagnostic mode and operational modes. All experiment commands will be contained in a pre-approved command table. Modifications to the command table will be allowed subject to the appropriate approvals from SET mission management and planning teams.

It is also assumed that the valid operational states of the SET payload (carrier and experiments) will be limited to a number (again small) of predetermined possibilities. In all cases the condition of the payload in terms of power consumption, data rates, etc. will be known.

Under the assumptions described above, it is reasonable to implement automatic commanding of instruments by the PI, without manual intervention of human operators. Commands for SET experiments are initiated either by PI's connected to the POCC via the Internet, or by personnel at the POCC Console (recognizing that the POCC Console may also be a "virtual console" connected to the POCC processor via the Internet). Automatic commands may also be initiated by the POCC or by the SET Carrier. The interface between PI facilities and the POCC will be implemented using secure Internet capabilities and the public network. The forms and procedures required for PIs to access the POCC will be stored at a POCC FTP site and downloaded to the PI facility using standard Internet browsers and protocols.

Carrier Commands are entered only from the POCC Console, with appropriate authorization.

Commands are examined by the POCC for correct authorization, format, validity etc. according to commanding rules established for each SET mission. Validated commands are then formatted into SET message units and are packed into CCSDS buffers for transmission to the appropriate host SOCC, according to the formats defined in the POCC to Host Spacecraft Operations Center ICD. Invalid commands are rejected and the PI is notified.

Requests for service from the host system (ground or flight) may also be sent to the host SOCC from the POCC. (Details of this capability - if any - depend upon the facilities made available to SET by a specific host mission and will be detailed in the Host/SET ICDs.)

SET communications packets are sent from the SOCC, uplinked to the host spacecraft and transferred to the SET carrier, as prescribed by the Host Spacecraft to SET Carrier ICD. Command packets are sent to the SET carrier, where they are analyzed and acted on as appropriate. Commands will variously modify the activities of the carrier, be immediately forwarded to experiments (during the next commanding cycle), or stored in the carrier command files for later execution.

Telemetry

The POCC will have the capability to interface with multiple host systems, each described by a separate Host-n to POCC ICD. Telemetry will be received from these multiple host systems and processed as described in this section. Again, it should be noted that a POCC processor may interface to only one mission, with the end-to-end system including multiple POCC processors to support multiple missions.

Experiments will gather data and make it available to the carrier, according to the formats and protocols described in the SET Carrier to Experiments ICD (an internal SET controlled document). Data are collected by the carrier from experiments on a regular basis and formatted for forwarding to the host spacecraft for downlink. This may involve buffering data into and out of storage in the SET carrier to accommodate host spacecraft downlink schedules. The amount of memory required in the carrier for this purpose is a function of overall data rates and the frequency of downlink available from the carrier. The following table gives an illustration of a carrier storage requirement sizing calculation.

Table 1. Carrier Memory Sizing

Assumptions

Host downlink frequency - once per 24 hours
Host data storage support – none
Number of SET-1 experiments – 10
Aggregate average data rate (all experiments) – 1 kbit/sec (average 100 b/sec/ exp)

Calculation

Carrier storage requirement (1000*60*60*24/8) = 10.8 Mbytes + Carrier housekeeping + margin

Conservative Carrier storage requirement = 16 Mbytes

Storage support from the host spacecraft will reduce the need for carrier on-board storage to that needed to support queue management requirements.

Carrier telemetry management may also involve formatting and packaging data packets to meet the host spacecraft downlink telemetry format requirements. SET will use CCSDS formats and protocols to transmit data between SET carriers and the POCC. CCSDS messages will be embedded into and extracted from the host message formats as required. All experiment data packets (telemetry and housekeeping), and all carrier housekeeping data, will be time-stamped by the carrier at the resolution of the carrier clock.

Data packets are received at the POCC from the SOCC and are decommutated for further action. Several levels of data storage are implemented by the POCC.

- All received telemetry is immediately stored at the POCC for a period dictated by mission assurance needs. This is a simple record of every telemetry packet received at the POCC from the SOCC. No real-time processing occurs on this data set.
- Carrier housekeeping telemetry is extracted from the received telemetry stream and forwarded to the POCC engineering analysis module for recording and further action, as appropriate.
- Experiment (data and housekeeping) telemetry, together with relevant carrier and host data (time, ephemeris, attitude, correlative environment data)

is immediately posted on the SET website for access by the PI for that experiment. The SET FTP site is implemented with appropriate rules of access and security, according to the data access rules implemented by the SET Project.

- Science data is forwarded to the SET Data Archive in an appropriate format and according to the rules established for the SET Project for data dissemination.

4 DETAILED DESCRIPTION

The following paragraphs present more detailed descriptions of the requirements for, and functionality of each component of the end-to-end data system.

Experiment PI Terminal

No special (i.e. non-COTS) hardware or software is required for a PI terminal. All capabilities of the SET data system will be available to experimenters via a standard computer workstation and secure Internet public access capabilities. A PI facility must have an Internet connection (dial-up or dedicated) and a workstation with an operating system that supports a standard Internet web browser.

Login— PI Access to the SET POCC will be via a secure Internet implementation. Password and other access control mechanisms will prevent unauthorized access to the system. Appropriate access controls will also be implemented at the POCC Console to preclude unauthorized access.

The PI will access the end-to-end data system via the SET Operations web site. Full access control and security measures including, but not necessarily limited to password control, site registration and authorization levels, and experiment identification will be implemented at the POCC and applied to all users seeking access to the system. The same access control and security provisions of the system will prevent unauthorized access.

The PI will first access the appropriate SET Operations website by using a mission specific URL and go through a login process, which will validate the right of access to the system and load a PI-Menu web page. Figure 2. SET Operations Web Pages shows a possible implementation strategy for accessing the SET POCC for multiple missions.

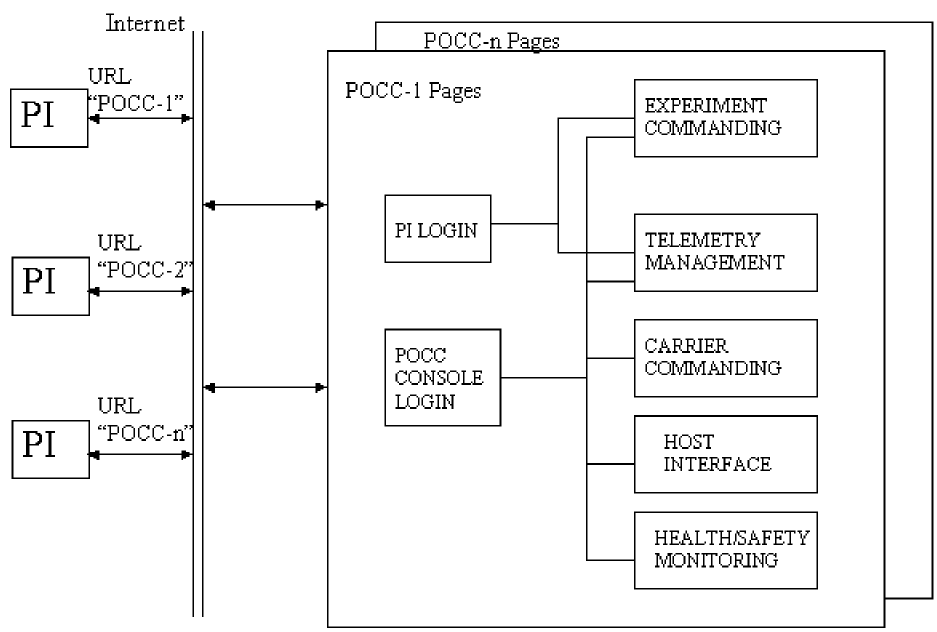

Figure 2. SET Operations Web Pages

Experiment Commanding—Before being allowed any access to the system, PIs must be positively correlated with a specific SET mission and experiment. Experimenters are restricted to commanding only their own experiment as verified from validated login information. Valid command codes and associated parameters are maintained in tables at the POCC for each experiment, using a common format for all experiments.

The Command screen allows the PI to specify a time for the command to be executed. If the Normal option is selected, the command will be processed to check for validity and correctness against the pre-stored command table, uplinked to the appropriate carrier via its host spacecraft and sent to the designated experiment for execution at the first opportunity. No delay will be deliberately introduced in relaying the command to the experiment. It should be noted, however, that the data system cannot control how long this normal commanding process might take. That is determined by the host uplink schedule and could include a delay of up to 24 hours or more from the time of submission of the command request by the PI.

Scheduled Commands that include a specified time of execution will be uplinked to the carrier according to the procedures described above. These commands will be stored by the carrier for transmission to the experiment on the command cycle immediately following the requested execution time. This will allow scheduled commands to be forwarded to the experiment within one command time cycle of the desired execution time. Scheduled commands must specify an execution time sufficiently far in the future from the time the command is processed by the POCC to ensure time for an extended uplink delay.

The system will allow a PI to have multiple experiments on multiple missions. However, it should be required that the PI login separately for each experiment. Commanding is restricted to one experiment at a time. To command a second experiment, the PI must login again, possibly using a different URL, specifying the second experiment. Login to command a new experiment on the same mission causes automatic logout from access to the previously active experiment.

Commands to upload software changes to an experiment or the carrier will be available. Use of software upload commands and verification and validation of software uploads is controlled by the SET Mission Manager.

Telemetry—All telemetry received at the POCC from an experiment (science data and housekeeping) is stored at a secure FTP site with access restricted to the PI Facility designated for that experiment, as soon as possible after receipt at the POCC. Positive notification of the availability of new telemetry is sent to the PI.

POCC Processor

Hardware Requirements— The SET Payload Operations Center Processor functionality will be implemented on commercially available computer workstations with sufficient capability and expansion potential to handle the needs of the entire projected SET mission set. Other than these standard COTS capabilities, no special requirements are levied on the POCC processors. It is expected that different processors, each running the same mission software, will be used to support multiple SET missions. Software implementation should be as generic as possible to allow new generations of processors to be used, as they become available, to support SET missions later in the Project.

POCC Processor Functionality— The POCC Processor suite hosts all of the web screens, edit files, FTP sites, etc., required to interface with PI terminals and with host data systems. It processes PI inputs and makes telemetry available to PI facilities and forwards data to the SET Data Archive. It also processes inputs from and outputs to the POCC Console. The following paragraphs detail the functionality of elements of the POCC Processor.

Login— When the appropriate POCC website is accessed via the Internet, a login screen is presented to the user, who enters access verification data and submits the form to the POCC for processing. The POCC processor validates the experimenter (PI) ID, password and, if implemented, the ID of the terminal from which the access request has been submitted. Failure of either the experimenter ID or the password to be validated results in an error message being returned to the requestor. If the login parameters are correct, the processor checks that the mission and experiment requested is valid for this PI. If not, an error message is returned; otherwise the Menu Screen is presented, giving the experimenter the options of experiment commanding, telemetry management, project communications, or housekeeping functions.

Appropriate login and identity verification procedures are also implemented at the POCC to ensure that only authorized mission personnel access the system through the POCC Console.

Commanding—Baseline SET experiments consist of 1 to 3 cards, with a maximum SET complement of approximately 10 experiments for each mission. The end-to-end data system will be sized to accommodate the maximum anticipated complement of experiments and expandable to support multiple missions. In addition, there may be box-level experiments that may not interface to a carrier according to the requirements of the baseline experiments/carrier ICD. To give SET maximum flexibility in commanding experiments, the POCC Processor maintains a command authorization table (See Table 2.). Each card position or additional box experiment has an entry in this table. If this entry indicates that the card position may be commanded, the commands for that card are processed in the normal way. If not, then any command directed to that position is rejected by the POCC Processor and not forwarded to the carrier and an error message is returned to the PI Facility. This table-driven capability allows a multi-card experiment to have commands sent to only one card, without making any demands on the carrier for detailed knowledge of experiment configuration. Command Table entries are modifiable from the POCC Console by authorized personnel.

It is also possible that SET experiments will be flown that interface directly with a host spacecraft, instead of connecting via a SET carrier. In such cases, interface requirements will be documented in a Host Spacecraft to Experiment ICD. Any experiment that does not connect to a SET carrier will have to meet the same host interface requirements as a SET carrier, with regard to interface to the SET POCC. The POCC will view the experiment to be the same as a carrier with a single experiment.

Telemetry Management—Telemetry data packets are received at the POCC from the carrier via the Host SOCC. SET CCSDS packets are extracted from the host format data packets that were downlinked from the carrier via the host spacecraft and stored immediately in the POCC data storage, with no further processing. Telemetry may also be received directly from the host system (SOCC or spacecraft) giving information about payload and mission performance.

Table 2. Example Command Table

Card #	Bus Address	Command Flag	Comments
Card 1	#0001	ON	Single Card Exp.
Card 2	#0002	ON	Single Card Exp.
Card 3	#0003	ON	Two Card Exp.
Card 4	#0004	OFF	not commanded
Card 5	#0005	ON	Single Card Exp.
Card 6	#0006	ON	Three Card Exp.
Card 7	#0007	OFF	not commanded
Card 8	#0008	OFF	not commanded
Card 9	#0009	ON	Single Card Exp.
Card 30	#0030	ON	Single Card Exp.

Analysis of the message header is performed to determine the type of message received from the SET Carrier or the host. Carrier and experiment housekeeping data are made available to the POCC Console Module for display and/or analysis. Experiment data packets (science and housekeeping) are made available to the experiment PI Facility as a binary file at a secure FTP site. Ephemeris and spacecraft attitude data are also appended to experiment telemetry, if such data are made available to SET by the host system.

Housekeeping— The POCC Processing Module will have the capability to maintain all of the control tables, command tables and edit criteria, and access control data for at multiple SET missions. Monitoring of engineering and housekeeping telemetry will be performed, together with appropriate analysis and trend evaluation, to determine overall mission performance.

Uplink Processing—The Uplink Processing module receives CCSDS packets from the Command Processing module and embeds them into packets for transmission to the appropriate host spacecraft via the host ground system. Messages are then queued to be sent over the host ground system communications interface. Details of this processing depend on the requirements of the host system and will be detailed in the POCC to Host SOCC ICD.

Downlink Processing—The Downlink Processing Module receives packets from the host ground system and extracts CCSDS packets for processing by the telemetry management module. Details of this processing depend on the requirements of the host system and will be detailed in the POCC to Host SOCC ICD.

POCC Console Processing—The POCC Console processing module receives inputs from the POCC Console and initiates actions to manage the SET mission. These actions include commands to the carrier and experiments, updates to SET control tables and requests for engineering data and analysis.

POCC Console

The POCC Console may be implemented via a secure input/output connection using the Internet. However, for mission assurance and security purposes there will also be a console that is collocated with, and hardwired to the POCC Processor at the SET control center at GSFC. Authorized personnel will use the console to manage the SET missions, communicate with SET payloads and with experimenters. Remote console operation via a secure Internet link should be considered to reduce operations cost by allowing unattended operations.

POCC Level 0 Data Storage

The POCC will routinely store all telemetry returned to the POCC from the SOCC, as soon as it is received and before any further processing. These data will not be processed, except as necessary to store them in a sequential, time ordered data structure. This data store is used for mission assurance purposes and will be a chronological storage of all telemetry received from the SET payload and its host with simple index capabilities for engineering and recovery access. Data in this storage will be maintained for long enough to support this need and then be discarded, and should be sized accordingly.

Host System

Host systems consist of a spacecraft, space/ground/space communications infrastructure, and a ground processing facility. The ground processing facility is designated as the Spacecraft Operation Control Center (SOCC) in this document. The internal details of host systems are not known and are not considered in the end-to-end data system concept, but it is assumed that uplink and downlink services will be available, and that commanding and telemetry interfaces will be available from the host SOCC.

The SET ground interface to a host system is between the POCC and the SOCC, and in space between the host spacecraft and the carrier. The requirements of these interfaces are given in the POCC to SOCC ICDs and the Host Spacecraft to SET Carrier ICDs. Details of these interfaces will not be known until a specific host system is selected for each SET mission. The SET Project will determine on a case-by-case basis whether the services offered by the host system constitute viable support for a SET mission. This paper assumes this to be the case, and that the end-to-end-system will accommodate whatever requirements are levied by the host system in terms of data rates, communications formats and service availability.

Carrier

Experiment Commanding—Three commanding scenarios are supported by SET. In all cases, commands are sent by the SET carrier to experiments individually, once during each major clock cycle. Mission Elapsed Time (MET) and a telemetry request are broadcast to all (active) experiments on a regular basis.

Normal Command. The first command scenario is when a command received from the ground (via the host) is forwarded to the experiment on the next available opportunity. There is no time correlation and no storage of commands (except for any immediate buffering during the commanding activity).

Scheduled Command. The second command type is received from the ground with an execution time in the future. This command is stored in the carrier for retrieval and delivery on the first command cycle following the command time. Scheduled commands received by the carrier whose time has already passed will be relayed immediately to the experiment with an error status being returned to the POCC.

Event Triggered Commanding. In some circumstances an experiment may set a command flag for the carrier (based on detecting an event of interest in the environment). When the carrier sees a command flag from the experiment, it will immediately (next command cycle) send a predefined set of commands to other experiments. The set of commands sent to experiments is predefined by the ground and stored in the carrier. The carrier will notify the ground when an event triggered command sequence occurs. Event triggered commanding may also occur when certain parameters received from experiments in telemetry messages fall into specified ranges. The carrier response is as described above.

Telemetry—The Carrier will retrieve telemetry from experiments on a regular basis. Each clock cycle, the carrier will read analog signal levels from all experiment cards, and construct an “analog telemetry message packet”. The carrier will record analog signal levels from each card attached to the carrier, according to the Analog Telemetry Table. In general every card will be monitored for dosimetry and temperature levels, and up to two additional signals will be monitored optionally, according to entries in the analog telemetry table, which is shown as part of Table 3. Telemetry Table.

Table 3. Example Telemetry Table

Card #	Exp. Addr.	Digital Telemetry	Analog Telemetry				Comments
			DOS	TMP	AN1	AN2	
Card 1	#0001	ON	ON	ON	ON	ON	Single Card Exp.
Card 2	#0002	ON	ON	ON	ON	ON	Single Card Exp.
Card 3	#0003	ON	ON	ON	ON	ON	Two Card Exp.
Card 4	#0004	OFF	ON	ON	OFF	OFF	No telemetry
Card 5	#0005	ON	ON	ON	ON	ON	Single Card Exp.
Card 6	#0006	ON	ON	ON	ON	ON	Three Card Exp.
Card 7	#0007	OFF	ON	ON	OFF	OFF	No telemetry
Card 8	#0008	OFF	ON	ON	OFF	ON	No telemetry
Card 9	#0009	ON	ON	ON	ON	ON	Single Card Exp.
Card 30	#0030	ON	ON	ON	ON	ON	Single Card Exp.

The Carrier will retrieve digital telemetry packets from each experiment on a regular basis. Each clock cycle the Carrier will poll each active experiment and read a telemetry packet over the serial digital data bus. The format of telemetry data packets is contained in the Carrier to Experiments ICD. The Carrier will maintain a state table indicating which cards are to be polled for telemetry (See Table 3.). An entry in this table for each card indicates whether or not the card is to be polled for telemetry data. Entries in this table are modifiable by command to the Carrier from the POCC.

Data Storage/Management—SET missions rely on a host spacecraft for downlink. Since the frequency of availability of downlink services is unknown, the carrier must have sufficient on-board storage to save all mission generated data for the maximum anticipated time between downlinks. The carrier should also not rely on any data storage services from a host spacecraft. The Carrier should contain sufficient storage to maintain at least 24 hours worth of experiment data (analog and digital) and housekeeping and carrier housekeeping telemetry. Based on an average, aggregate data rate of 1 kilobit per second for all experiments, this on-board storage sized at 16 Mbytes will be required, as shown in Table 1.

Host Interface—The carrier receives uplink telemetry from the host that contains commands for experiments and for the carrier itself that have been forwarded from the SET POCC. It may also receive commands generated by the host system (e.g. Payload Power Off). Commands from the host system are acted upon according to the requirements of the Carrier to Host Spacecraft ICD. Commands from the POCC are extracted from the host format and acted upon as described in this document. Telemetry gathered from SET experiments, as well as carrier housekeeping data are buffered as necessary, formatted and sent to the host for delivery to the POCC.

Experiment

SET experiments are connected to the carrier via several data interfaces. These interfaces are fully described in the Carrier to Experiments ICD. Each SET experiment may consist of from one to three cards and the level of connectivity implemented for each card can vary, according to the needs of the individual experiment. This is depicted in Figure 3. Experiment to Carrier Connectivity.

Four analog signals are implemented by SET at each experiment port. The first two of these, temperature and dosimetry are activated for every card. The other two are experiment dependent and may not be monitored by the carrier, as specified in the Carrier to Experiment ICD for the particular experiment. Time distribution, commanding and telemetry acquisition are available for all cards but may not be implemented. A multi-card experiment, for example, may wish to receive commands and report telemetry at only one point across a single card interface. The carrier will maintain a state table that determines which cards are to be commanded and from which cards telemetry is to be gathered and the optional analog signals are to be monitored. This information is depicted in Table 3, described earlier.

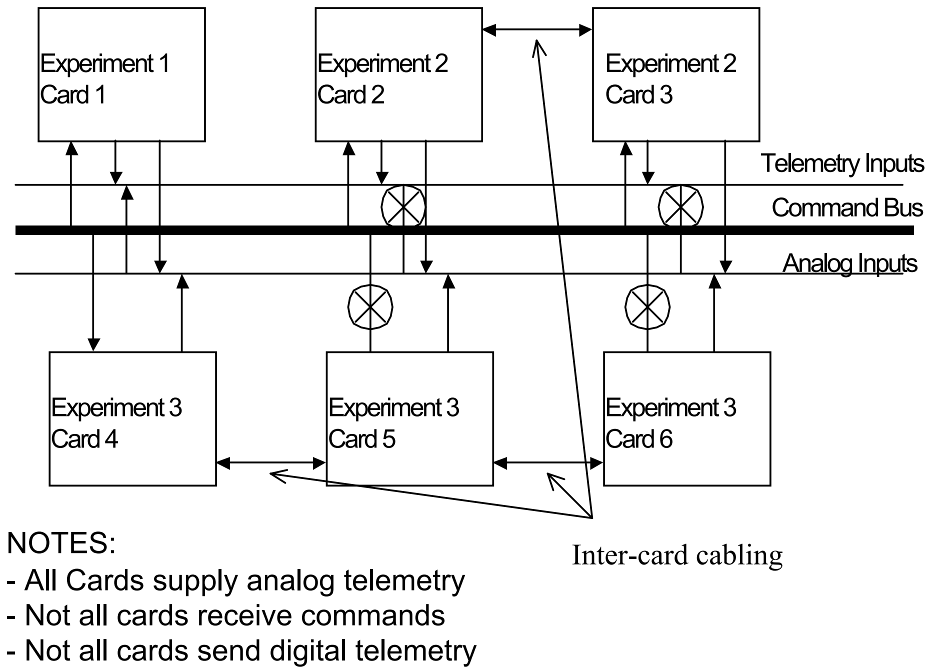

Figure 3. Experiment to Carrier Connectivity

SET will support experiments that connect directly to a host spacecraft and not to a SET carrier. In these cases, it is the responsibility of the experiment to interface with the host spacecraft directly. A Host Spacecraft to Experiment ICD will detail the requirements of this interface. Additionally, the experiment is responsible for packaging telemetry in CCSDS packets for transmission to the SET POCC via the host spacecraft. The POCC will treat such experiment telemetry as though it came from a SET carrier.

SET Simulation Lab

The SET Simulation Lab is established at GSFC and will be used to verify experiment functionality, to test elements of the end-to-end-data system and to trouble-shoot carrier and experiment problems both during mission development and flight operations. The functionality if the SET Simulation Lab is shown in Figure 4. SET Simulation Lab Overview.

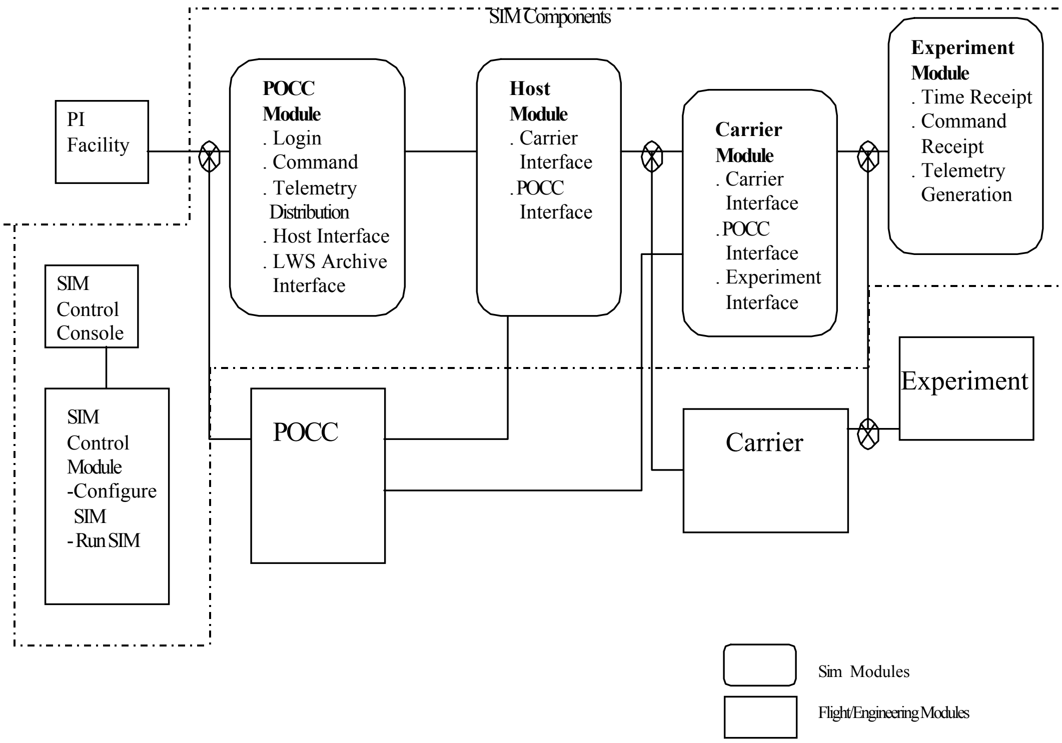

Figure 4. SET Simulation Lab Overview

The Simulation Lab will contain modules to simulate all of the elements of the SET System: the carrier, experiments, the host system and the POCC. All elements of the host system, including both ground and flight components will be treated as a single black box and simulated only at the SET input and output points, according to the requirements of the Host to carrier and host to POCC ICDs. It should also be possible to configure the Simulation Lab to either simulate each of the components of the SET System, or to work with the actual engineering models or flight devices. The actual configuration of the Simulation Lab for a particular test will be controlled from the Simulation Control Console. The SET Simulation Lab must also be capable of supporting multiple SET missions, with an independent and potentially different configuration for each mission. A probable implementation strategy is to have multiple systems, each supplying simulation services to a single SET mission, or to particular mission phases.

5 CONCLUSION

This paper has described a concept for an end-to-end data system to support multiple, low-cost technology validation missions. Special consideration has been given to the fact that these missions will be launched on different, and as yet unidentified host spacecraft. The concept is also based on minimizing operations costs by using commercial capabilities and the public network (Internet) to communicate between experimenters and mission control.

Biography

***Geoff Giffin** is a systems and technology consultant in the fields of emerging technology, space systems, systems engineering and satellite communications. He has performed numerous assignments for NASA and other government clients, the aerospace industry and financial and insurance organizations, to evaluate existing and emerging technologies and the impact they will have on the technical and management/financial aspects of space systems. He previously managed advanced technology programs for NASA, and was a spacecraft software systems engineer at the Jet Propulsion Laboratory. Prior to that he was a real-time systems programmer developing advanced communications systems for industrial, law enforcement and other applications. He has a BSc in physics from the University of North London and a masters degree in liberal arts from St. John's College, Annapolis.*

Barry Sherman *is a NASA civil servant with many years experience in developing flight instruments. He Currently is the Mission Manager for the SET-1 Mission which is part of the Living with a Star/SET Project. Prior to that he was the Instrument Manager for the UVCS Instrument on the SOHO Spacecraft. He has also worked on the External Payloads portion for the NASA Space Station. He has a BSc in physics from Adelphi University of Long Island New York and a Masters of Science from the Polytechnic Institute of New York.*